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Comparative Shortwall and Room-and-Pillar Mining Costs

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Comparative Shortwall and Room-and-Pillar Mining Costs

By L. E. Green and E. R. Palowitch

March 3 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

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COMPARATIVE SHORTWALL AND ROOM-AND-PILLAR MINING COSTS

by

L. E. Green[1] and E. R. Palowitch[2]

ABSTRACT

For shortwall mining to be profitable, the additional capital investment of about $1 million for shortwall roof supports must be offset by decreased total operating costs and/or increased coal production. The Bureau of Mines therefore conducted a demonstration project to compare shortwall and room-and-pillar mining.

Daily two-shift production from the Bureau of Mines-Beth-Elkhorn Corp. shortwall demonstration project averaged 975 tons of raw coal, compared with 905 tons from a room-and-pillar unit operating under similar conditions. The estimated direct operating costs for the shortwall and room-and-pillar units were $4.21 and $4.03 per ton, respectively.

The profitability of the shortwall system was found to depend not only on the increased depreciation cost of the powered roof supports and the decreased cost of supplies and materials but also on such factors as the fixed and variable indirect costs and the selling price of the coal. Shortwall mining was demonstrated to be a viable alternative to room-and-pillar mining.

INTRODUCTION

The Bureau of Mines and the Beth-Elkhorn Corp. under a cooperative agreement have been demonstrating shortwall mining since January 1973 in the 2 West section of Beth-Elkhorn's No. 22 mine in Letcher County, near Deane, Ky. (fig. 1). Mining is in the Elkhorn No. 3 coalbed, which is 48 to 54 inches thick and lies under 150 to 800 feet of cover.

This report compares the cost of mining coal by two different mining systems--shortwall and room-and-pillar. Because both systems are operating in close proximity with each other in the 2 West section of the mine, in the same coalbed, and under similar geologic conditions, the indirect costs for general

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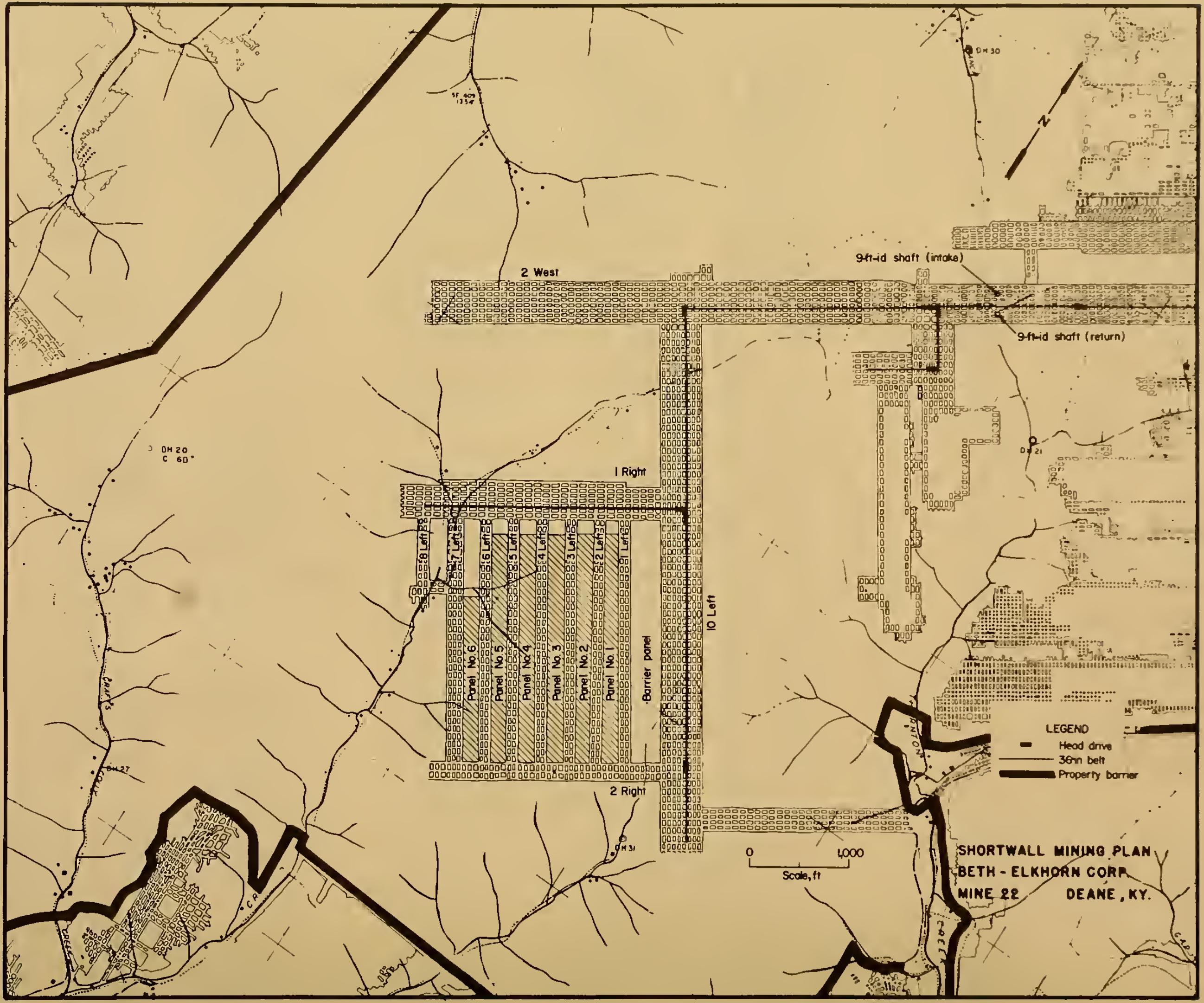

FIGURE 1. - Hendrix No. 22 mine, 2 West section.

overhead, general mine depreciation, transportation, preparation, waste disposal, taxes, insurance, and all other costs outby the operating section and common to both systems were not separately identified but were added directly to the direct operating costs (direct labor, material, utilities, and face equipment depreciation). Production, supervision and maintenance labor, face equipment depreciation, materials, and utilities costs were obtained from the operator and from pertinent literature.[3]

DIRECT MINING COSTS

The two systems being compared are adjacently located in the 2 West section of Hendrix No. 22 mine. D unit, the shortwall unit, develops 150-foot-wide panels by driving three entries 2,400 feet deep and extracting these shortwall panels with a continuous miner and shuttle cars under powered roof supports; B unit, a standard room-and-pillar unit, develops sets of eight entries and subsequently extracts these pillars on retreat. Both units normally work two production shifts and one maintenance shift per day, 5 days per week. Both employ 10-man production crews and essentially the same coal cutting, loading, and haulage equipment. On the average, the raw coal produced contains 22 percent reject.

Room-and-Pillar System

The standard room-and-pillar system (fig. 2) was used by B unit. The unit consisted of a 10-man production crew working two production shifts per day. The equipment was maintained by a four-man maintenance crew on the non-production shift. The face production equipment included a continuous miner, a roof-bolting machine, two shuttle cars, one battery-operated scoop tractor, and a section belt ratio feeder supplying a 36-inch belt conveyor.

The production crew initially drove eight entries, cutting the coal with the continuous miner and hauling it with the two shuttle cars to the ratio feeder. The entries and crosscuts are driven 20 feet wide on 50- and 75-foot centers, respectively (fig. 2). During development, belt conveyor, track, trolley wire, high-voltage cable, and waterline are installed in one of the middle entries. Concrete block stoppings are installed in the crosscuts. Roof bolts are used throughout the section to support the roof. The MESA-approved roof support plan prescribes the use of 5/8-inch-diameter bolts 5 feet long placed on 4-1/2-foot centers across the width of the entry (not to

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[3] Duda, J. R., and E. L. Hemingway. Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Coal Mines Developed for Longwall Mining. Miner With Annual Production of 1.3 and 2.6 Million Tons by Longwall Mining From a 48-Inch Coalbed. BuMines IC 8720, 1976, 32 pp.
Katell, S., E. L. Hemingway, and L. H. Berkshire. Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Coal. Miner With Annual Production of 1.03 to 3.09 Million Tons From a 48-Inch Coalbed. Revision of Information Circular 8641. BuMines IC 8689, 1975, 32 pp.
Sabatini, J., and L. A. Conley. Bibliography of Investment Costs, Operating Costs, and Related Economic Information for the Mineral Industries, January-December 1975. BuMines IC 8716, 1976, 58 pp.

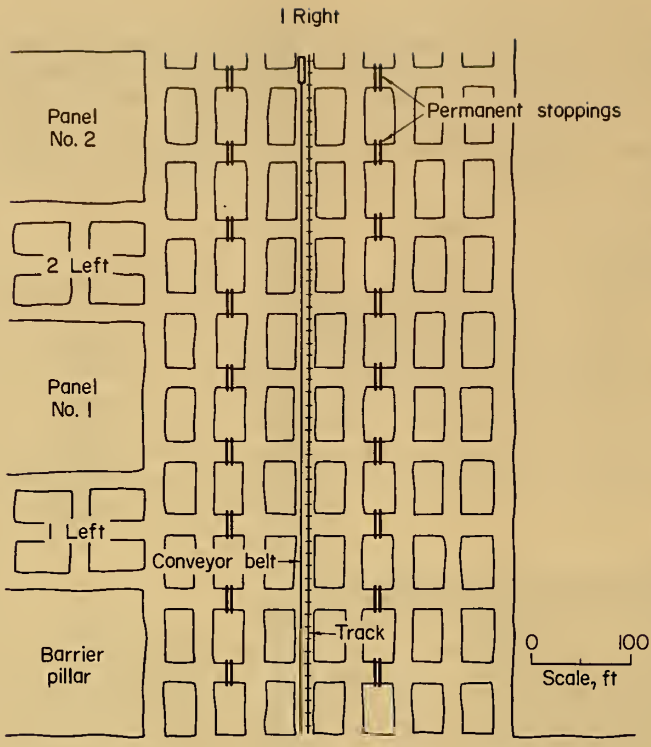

FIGURE 2. - Room-and-pillar arrangement, 2 West section, B unit.

exceed 22 feet) and on 4-foot centers in the direction of advance.

At the completion of the eight-entry development, the pillars are extracted on retreat. The same equipment and personnel used for development are used for retreat. During retreat the installed track, trolley wire, conveyor, high-voltage cable, and waterlines are recovered. The sequence of extracting the pillars is shown in figure 3.

During a 16-month period prior to the installation of the shortwall system, B unit's production averaged 888 tons per day; during the shortwall demonstration period (January 2, 1973, to January 19, 1977) B unit's production while developing 1 Right averaged 905 tons per day.[4]

Although the roof control plan for the Hendrix No. 22 mine indicates virtually complete pillar extraction, actual room-and-pillar recovery averages about 85 percent.

The 10-man production crews mining coal on both the development and retreat phases of the room-and-pillar mining system represent only the personnel working at the face. The same is true of the four-man maintenance crew. The personnel cost necessary for all general inside labor not performed by the direct operating crews is included in the indirect cost. This includes such functions as installing and recovering track, trolley wire, waterline, and concrete block stoppings.

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[4] Palowitch, E. R., and G. C. Litton, Jr. Shortwall Mining at the Hendrix No. 22 Mine. Proc. 1st Symp. Underground Coal Mining, NCA/BCR Coal Conf. and Expo II, Louisville, Ky., v. 1, Oct. 21-23, 1975, pp. 152-164.

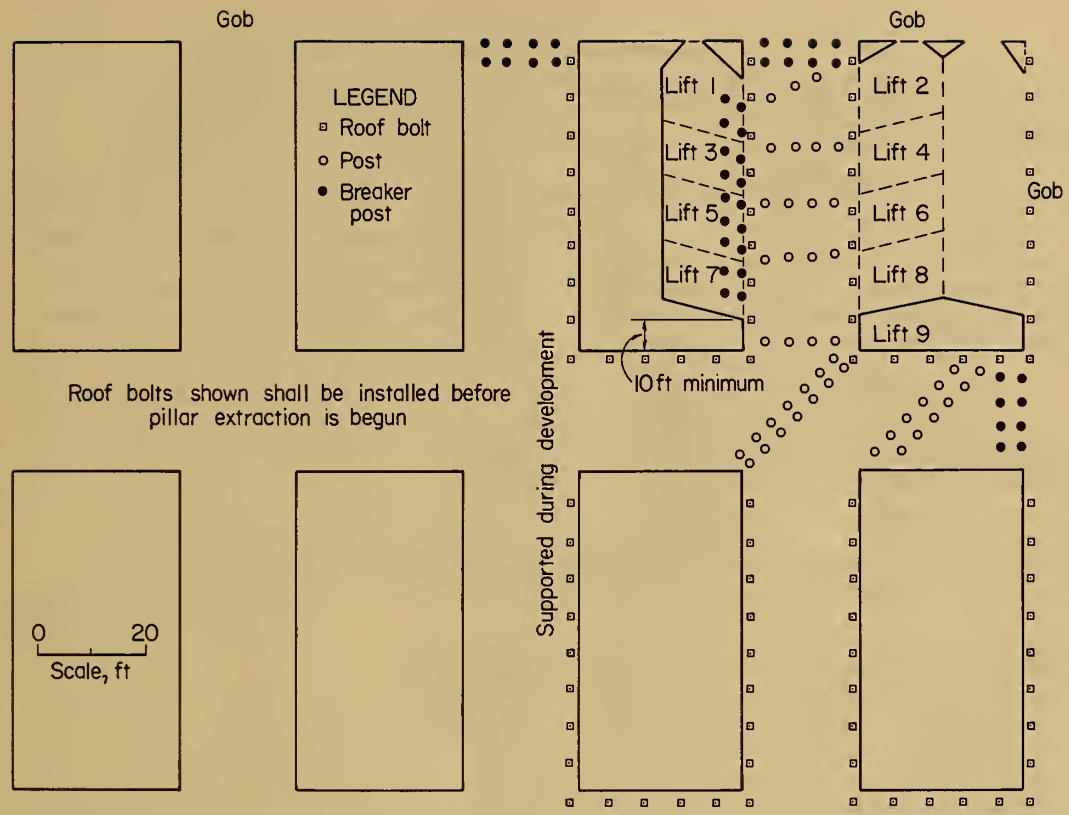

FIGURE 3. - Pillar extraction sequence.

The specific production crew composition and cost for B unit is detailed in table 1; table 2 shows the maintenance crew composition and cost.

TABLE 1. - Production crew composition and cost, B unit

Job classification	Daily rate	Number	Cost
Continuous miner operator.....	$57.20	1	$57.20
Continuous miner helper.......	57.20	1	57.20
Roof bolter operator..........	57.20	1	57.20
Roof bolter helper............	57.20	1	57.20
Shuttle car operator..........	51.20	2	102.40
Scoop operator................	51.20	1	51.20
Mechanic......................	57.20	1	57.20
General inside labor..........	48.91	1	48.91
Foreman.......................	90.00	1	90.00
Total cost per shift.....	-	10	578.51
Unit cost per ton........	-	-	1.28

TABLE 2. - Maintenance crew composition and cost, B unit

Job classification	Daily rate	Number	Cost
Mechanic......................	$57.20	4	$228.80
Total cost per shift.....	-	4	228.80
Unit cost per ton........	-	-	.25

The wage rates used were those in effect November 1976 per the National Bituminous Coal Wage Agreement of 1974. Cost-of-living allowance (COLA) and shift differential were not included in the direct labor cost. COLA as of October 1976 amounted to 52 cents per hour. Shift differential is 15 cents per hour for the afternoon shift and 20 cents per hour for the midnight shift.

Another direct operating cost is depreciation of the face equipment. A listing of the equipment and depreciation costs is given in table 3. Straight-line depreciation with zero salvage value for all equipment was assumed. The initial equipment costs reflect 1976 prices.

TABLE 3. - Capital equipment and depreciation costs, B unit

Equipment	Initial cost	Life expectancy, years	Annual depreciation
Continuous miner.................	$280,000	7	$40,000
Shuttle cars (2)................	160,000	8	20,000
Ratio feeder....................	45,000	8	5,625
Roof bolter.....................	53,000	8	6,625
Mantrip jeep....................	17,000	8	2,125
Power center....................	28,000	8	3,500
Scoop...........................	46,000	5	9,200
Battery charger.................	5,000	5	1,000
Supply materials................	31,000	8	3,875
Supply car......................	3,000	8	375
Rock duster.....................	3,000	8	375
Pump pressure...................	3,000	10	300
Section tools...................	10,000	10	1,000
Switches........................	2,700	10	270
Miscellaneous[1] (2,400 feet).....	275,000	10	27,500
Total.....................	961,700	-	121,770

[1] Reflects recoverable materials of a capital nature such as trolley wire and track. Included items are identified in appendix B.

Based on an average production rate of 905 tons per day and 220 production days per year, the depreciation charge is $121,770 per year, equivalent to $0.61 per ton.

Material costs (table 4) were estimated by charging the materials actually consumed during a 150-foot advance of the eight-entry room-and-pillar section (B unit). A distinction was made between those materials used during development and those used during retreat.

TABLE 4. - Material cost summary, B unit

Category	Development	Pillar extraction	Weighted average[1]
Total cost per 150-foot section..........	$12,047.00	$6,895.00	$10,102.00
Total unit cost per ton..................	1.79	1.69	1.75

[1] Based on 6,730 tons of development coal and 4,080 tons of pillar coal per 150-foot section (appendix A).

The materials can be classified into two broad categories: (1) Materials that are completely consumed during mining, such as roof bolts, rock dust, and timber; and (2) materials that are recovered and reused, such as trolley wire and track. The recoverable materials are capital in nature; hence their depreciation cost was included in the fixed depreciation costs.

Appendix A shows the calculation of the coal tonnage produced during the advancement and retreat of a 150-foot section. Appendix B lists all the materials used, their estimated cost, and the assumptions made in their costing.

The material costs for both development and retreat, weighted in proportion to the coal production in a normal eight-entry production section, are thus $1.75 per ton.

Face utility costs for water and electricity vary with the type of equipment used for mining. Katell, Hemingway, and Berkshire[5] estimated water required for a typical room-and-pillar section at 3,000 gallons per shift; at $0.10 per 1,000 gallons, this amounts to approximately $1 per day. Electrical power costs are directly related to the rated horsepower and duty cycle of the face equipment. Continuous miner and shuttle car operations were time-studied and reported by Palowitch and Litton.[6] Daily power requirements are shown in table 5.

TABLE 5. - Electrical power requirements, B unit

Equipment	Total hp	Hr used per day	Load, kw	Kwhr per day
Continuous miner...........	535	6	399	2,394
Shuttle cars (2)...........	290	6	216	1,296
Ratio feeder...............	100	6	75	450
Roof bolter................	50	12	37	444
Mantrip jeep...............	15	4.5	11	50
Supply motor...............	80	1.5	60	90
Conveyor drive.............	75	16	56	896
Pumps, etc.................	40	24	30	720
Total.................	1,185	-	884	6,340

Based on a $0.02-per-kilowatt-hour electric rate, the daily face power cost is $127. The combined water and electric utility cost is thus $0.14 per ton.

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[5] Second work cited in footnote 3.

[6] Work cited in footnote 4.

The total direct operating costs calculated for an eight-entry room-and-pillar section were $3,644 per day and $4.03 per ton. Table 6 summarizes these costs, which include direct production and maintenance labor, equipment depreciation, materials, and utilities.

TABLE 6. - Direct operating costs, B unit

Cost category	Daily	Per ton
Production labor...............	$1,158	$1.28
Maintenance labor..............	229	.25
Depreciation...................	554	.61
Materials......................	1,575	1.75
Utilities......................	128	.14
Total....................	3,644	4.03

Shortwall System

The shortwall operation (D unit) at Hendrix No. 22 is depicted in figure 4. D unit is manned by a 10-man production crew, working 2 production shifts per day, 5 days per week. A five-man crew maintains the equipment on the evening shift of each workday.

The primary mining equipment employed by D unit consists of a continuous miner, two shuttle cars, a battery-powered scoop tractor, a section belt, a ratio feeder, a roof-bolting machine, and a shortwall powered roof support system. The coal is cut and loaded with a continuous miner and hauled to a section belt ratio feeder by two shuttle cars.

The shortwall panels are developed by driving a set of three entries 20 feet wide on 50-foot centers with 20-foot-wide crosscuts on 75-foot centers to a depth of 2,400 feet to create a 150-foot-wide by 2,400-foot-long shortwall panel.[7] The development entries serve first as headgate entries and subsequently as tailgate entries for the next panel. Roof bolts are used throughout the development entries to support the roof. Concrete block stopping are installed in the crosscuts as development progresses. A belt conveyor, trolley wire, high-voltage cable, waterlines, and track are installed in the center entry.

At the inby end of the 2,400-foot-deep development entries, 150 feet of additional three-entry bleeders are driven perpendicular to establish a shortwall face (fig. 5). No track, conveyor, cable, or waterline is installed in these entries.

The same equipment and face crews used to develop the entries are used to mine the coal and haul it from the shortwall face to the panel conveyor. The average lift across the face is 4.5 feet high and 10.5 feet wide. It takes approximately 1.7 hours to make a complete lift and requires 69 to 70 shuttle car trips at a payload of 4.3 tons to transport the coal from the face to the

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[7] Palowitch, E. R., and T. J. Brisky. Designing the Hendrix No. 22 Shortwall. Min. Cong. J., v. 59, No. 6, June 1973, pp. 16-22.

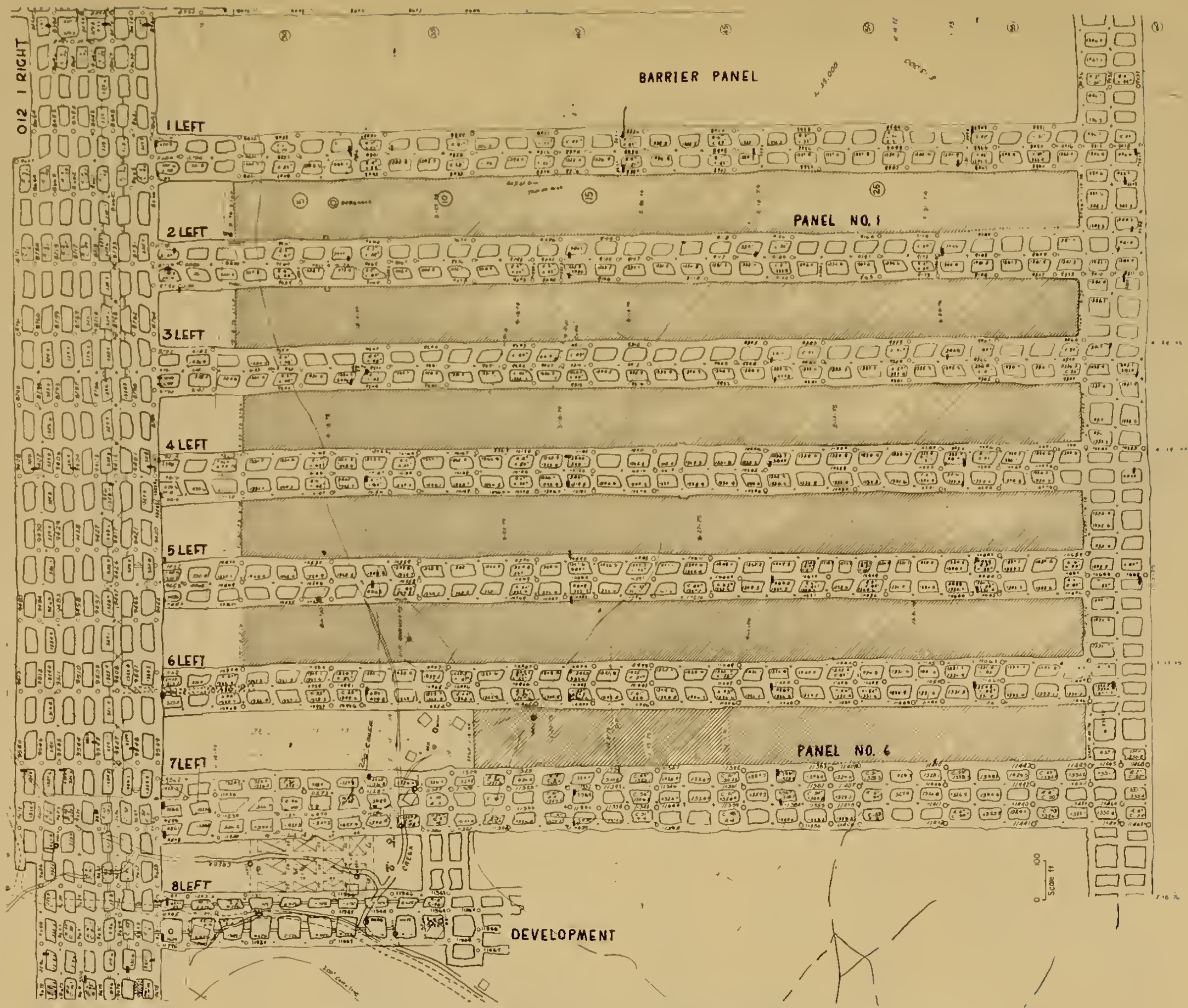

FIGURE 4. - Shortwall area of the Hendrix No. 22 mine.

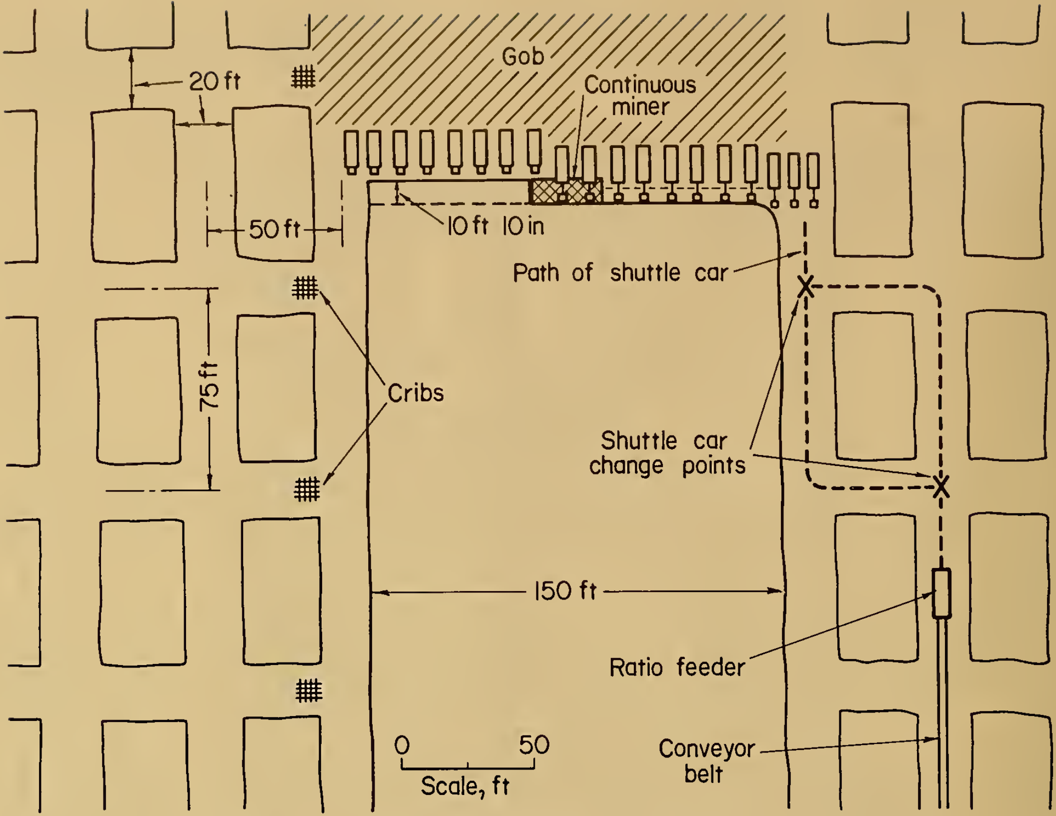

FIGURE 5. - Shortwall arrangement, 2 West section, D unit.

breaker-feeder. The average time to clean up and advance the face after each lift is 33 minutes. A battery-powered scoop crosses the face after each lift to collect loose coal and haul it to the headgate.

Approximately 200 feet of the developed shortwall panel is left standing as a barrier pillar to protect the main entries.

Once the panel of coal is mined, the production crews pull the roof supports off the face and store them in an entry. The production crews move the mining equipment to begin development of another panel. A separate three-man crew moves and sets up the stored roof supports onto the next, already developed, shortwall face. This crew also performs necessary maintenance on the chocks as well as general cleanup and face preparation for the shortwall panel.

No production is lost between panels in the normal mining cycle because the shortwall supports are set up on the new panel during the development of the succeeding panel.

During the period January 2, 1973, to January 19, 1977, six full shortwall panels were developed and extracted; the development of a seventh panel was started but had to be abandoned after driving only about 900 feet because of adverse roof conditions (fig. 4).

As shown in table 7, total raw coal production from the seven and one-third sets of panel development entries and from the six panels during the period January 2, 1973, to January 19, 1977, was 691,749 tons, of which 306,791 tons was development coal and 384,958 tons was retreat (shortwall) coal. Average daily production from the shortwall ranged from a low of 856 tons in the first panel to a high of 1,166 tons in the fourth panel, while average daily development production ranged from 714 on 1 Left to 1,032 on 7 Left. Productivity ranged from 29 to 47 tons per face-manshift. The highest daily production was 2,027 tons.

Overall, D unit's daily performance showed 913 tons on development and 1,031 tons on retreat (shortwall extraction) for a weighted average of 975 tons.

Because the chain pillars between the development entries are not recovered, coalbed recovery with the shortwall system is approximately 82 percent.

The production face crew on the shortwall consisted of 10 men, as shown in table 8. Table 9 shows the makeup and cost of the maintenance crew, and table 10 shows the composition and cost of the roof support moving crew.

The equipment used in shortwall mining is identical to that used for room-and-pillar operation with one significant addition--the powered roof supports. The support system used in this particular case consisted of 42 four-leg, 500-ton-capacity, 42-inch-wide chocks. The chocks were set on 48-inch centers and attached to an articulated reference rail to maintain proper spacing and alinement across the face. For purposes of this study, the chocks were costed at an installed 1976 value of $1 million. A life expectancy of 10 years was assumed. Although a roof bolter normally will be used only occasionally while mining a shortwall panel, its depreciation was fully charged to the shortwall system.

Annual straight-line depreciation cost for the shortwall roof supports is $100,000. This raises the total annual depreciation from $121,770 per year or $0.61 per ton for a room-and-pillar system (table 3) to $221,770 per year or $1.03 per ton for the shortwall system.

Material costs were estimated in the same manner as for the continuous room-and-pillar system. Materials used during panel development and panel extraction were individually identified because of the distinct difference in production and costs between the two mining phases.

TABLE 7. - Summary of D unit production, January 2, 1973-January 19, 1977

Dates	Activity	Shifts worked	Coal produced, raw tons		Productivity, tons per face-manshift
			Total	Daily	
1-02-73 3-02-73	Develop barrier pillar (1 Left)..	76	27,115	714	29
3-05-73 4-29-73	Develop panel 1 (2 Left).........	76	36,189	952	38
4-30-73 6-30-73	Develop panel 2 (3 Left).........	93	47,465	1,021	41
1-14-74 4-18-74	Mine panel 1.....................	143	61,222	856	34
4-22-74 6-18-74	Develop panel 3 (4 Left).........	84	40,488	964	39
7-08-74 10-18-74	Mine panel 2.....................	125	66,413	1,063	43
10-21-74 1-20-75	Develop panel 4 (5 Left).........	60	31,380	1,046	42
1-22-75 4-23-75	Mine panel 3.....................	127	71,160	1,121	45
4-28-75 6-27-75	Develop panel 5 (6 Left).........	76	37,170	978	39
7-14-75 10-30-75	Mine panel 4.....................	121	70,554	1,166	47
11-03-75 2-18-76	Develop panel 6 (7 Left).........	129	66,567	1,032	41
2-19-76 6-03-76	Mine panel 5.....................	134	66,153	987	39
6-11-76 9-09-76	Develop panel 7 (8 Left).........	78	20,417	523	21
10-26-76 1-19-77	Mine panel 6.....................	97	49,456	1,020	41
	Total development..........	672	306,791	913	37
	Total shortwall............	747	384,958	1,031	41
	Grand total................	1,419	691,749	975	39

TABLE 8. - Production crew composition and cost, D unit

Job classification	Daily rate	Number	Cost
Continuous miner operator	$57.20	1	$57.20
Continuous miner helper	57.20	1	57.20
Shuttle car operator	51.20	2	102.40
Chock operator	51.20	1	51.20
Mechanic	57.20	1	57.20
Roof bolt operator	57.20	1	57.20
Roof bolt helper	57.20	1	57.20
Scoop operator	51.20	1	51.20
Foreman	90.00	1	90.00
Total cost per shift	-	10	580.80
Unit cost per ton	-	-	1.19

TABLE 9. - Maintenance crew composition and cost, D unit

Job classification	Daily rate	Number	Cost
Mechanic	$57.20	4	$228.80
Mechanical helper	49.48	1	49.48
Total cost per shift	-	5	278.28
Unit cost per ton	-	-	.29

TABLE 10. - Roof support moving crew composition and cost, D unit

Job classification	Daily rate	Number	Cost
Chock operator	$51.20	1	$51.20
Continuous miner helper	57.20	1	57.20
Foreman	90.00	1	90.00
Total cost per shift	-	3	[1]198.40
Unit cost per ton	-	-	.07

[1] Average 36 production days for moving crew and 108,000 tons for 1 complete shortwall cycle of development and panel extraction.

Appendix B identifies all the materials used, their cost, and costing assumptions. As a complete cycle of the shortwall system includes developing 2,670 feet of a three-entry system and extracting a 2,200-foot-long by 150-foot-wide shortwall panel, the individual material unit costs were weighted in proportion to the extracted coal tonnages attributable to each of these two phases. A material cost summary is shown in table 11.

TABLE 11. - Material cost summary, D unit

Category	Development	Retreat	Weighted average[1]
Total cost per 150-foot section	$4,290.00	$6,265.00	$5,601.00
Total cost per ton	1.81	1.34	1.50

[1] Based on 2,370 tons of development coal and 4,675 tons of retreat coal per 150-foot section (appendix A).

The shortwall system daily utility costs are assumed to be the same as for the room-and-pillar system. The roof bolter is used sparingly while mining the shortwall panel, but this cost saving is offset by the cost to operate the hydraulic system for the chocks. The utility cost is estimated at $128 per day, or $0.13 per ton.

A summary of the shortwall direct operating costs is given in table 12.

TABLE 12. - Direct operating costs, D unit

Cost category	Daily	Per ton
Production labor..............	$1,162	$1.19
Maintenance labor.............	278	.29
Chock-moving labor............	68	.07
Depreciation..................	1,008	1.03
Materials.....................	1,463	1.50
Utilities.....................	128	.13
Total....................	4,107	4.21

TOTAL MINING COSTS

The total cost of mining includes the direct operating costs and the indirect costs. Table 13 gives direct operating costs determined for the room-and-pillar system (table 6) and for the shortwall system (table 12) at average raw coal production levels of 905 tons per day and 975 tons per day, respectively.

TABLE 13. - Summary of total direct operating costs per ton

Cost category	Room-and-pillar	Shortwall
Production labor................	$1.28	$1.19
Maintenance labor...............	.25	[1].36
Face depreciation...............	.61	1.03
Materials.......................	1.75	1.50
Utilities.......................	.14	.13
Total unit cost per ton of raw coal...............	4.03	4.21

[1] Includes chock moves.

The indirect costs incurred in the production of coal must be included in determining the total mining cost. Specific costs include general mine and payroll overhead, transportation, depreciation, labor, insurance, preparation, waste disposal, and taxes. These indirect costs consist of both fixed and variable elements with respect to production. Insurance, depreciation, and property taxes are examples of fixed indirect costs, which remain essentially constant regardless of the amount of coal produced. The variable indirect costs include expenses for such items as coal royalties, excise taxes, and contributions to the United Mine Workers of America Trust Fund. These costs are a direct function of the level of coal production. In general, only a small proportion of total indirect costs is variable in nature.

Conventional accounting practice spreads the indirect costs of production equally over each unit produced to arrive at a total unit cost of production. As a major portion of the indirect costs are fixed, any increase in annual production will spread this fixed annual cost over more units and hence will provide a lower total cost per unit.

Although indirect costs vary appreciably between mines, an assumption was made of these costs to allow comparing the total costs of the two mining systems. A fixed indirect cost of operating a hypothetical mine with a single coal-producing section operating two production shifts per day was estimated at $4 million annually. The variable portion of the total indirect costs was estimated at $3 per ton of clean coal.

The production and cost experience gained at Hendrix No. 22 was used as a basis for comparing the economics of the two systems: the room-and-pillar system produced an average of 905 tons of raw coal daily at a direct cost of $4.03 per ton (706 tons of clean coal per day at a direct cost of $5.17 per ton); the shortwall system produced an average of 975 tons of raw coal per day at a direct cost of $4.21 per ton (761 tons of clean coal daily at a direct cost of $5.39 per ton). The total operating costs of the two mining systems, based on clean coal production, are depicted in table 14.

TABLE 14. - Operating costs summary, hypothetical mine

Mining system	Annual clean coal production, tons	Operating costs						
		Direct		Variable indirect		Annual fixed indirect, millions	Total	
		Per ton	Annual	Per ton	Annual		Annual	Per ton
Room and pillar.....	155,320	$5.17	$802,373	$3.00	$465,960	$4	$5,268,333	$33.92
Shortwall...	167,420	5.39	903,045	3.00	502,260	4	5,405,305	32.28

Because the shortwall system produces an average of 12,100 tons of clean coal per year more than the room-and-pillar system (167,420 tons versus 155,320 tons), the reduction of $1.86 per ton in indirect costs ($25.75 versus $23.89) more than offsets the increased direct cost of $0.22 per ton ($5.39 versus $5.17) for the shortwall coal. Thus, under the above assumptions, the total cost of shortwall coal at this hypothetical mine is $1.64 per ton less than the cost of room-and-pillar coal ($33.92 versus $32.28)

PROFITABILITY

Using the operating costs developed above, economics of the two systems can be compared to determine the profitability of the shortwall investments. The lower total operating costs per ton for the shortwall result in higher gross profit. If the selling price of clean coal is assumed to be $40 per ton, this cost benefit results in an additional annual gross profit of $347,028 per year. This increased profitability of the shortwall system in the hypothetical mine is illustrated in table 15.

TABLE 15. - Comparative profitability, hypothetical mine

Mining system	Total revenues		Total operating costs		Gross profits	
	Per ton	Annual	Per ton	Annual	Per ton	Annual
Room and pillar.	$40.0	$6,212,800	$33.92	$5,268,333	$6.08	$944,467
Shortwall.......	40.0	6,696,800	32.28	5,405,305	7.72	1,291,495

Some businessmen consider all fixed indirect costs as prepaid or recovered in an existing profitable enterprise. Under these circumstances only the variable portion of the indirect costs and the direct operating costs would be attributed to any increased production in evaluating a proposed capital investment. Under this philosophy, the extra daily shortwall production of 55 tons of clean coal would be costed at $8.39 per ton. With coal selling at $40 per ton, this represents a gross profit, before taxes, of $31.61 per ton. Comparing the increased annual gross profit to an initial shortwall investment of $1 million, the investment would be recovered in 2.6 years.

ANNUAL COST AND CAPITAL RECOVERY ANALYSIS

An annual cost analysis was performed (appendix C) with the following assumptions: (1) As the run-of-mine coal averaged 22 percent reject during the demonstration period, raw coal production was adjusted accordingly to reflect salable clean coal tonnages when determining gross income from sales; (2) the salable clean coal was valued at $40 per ton; (3) depletion was estimated at 10 percent of sales in accordance with Internal Revenue Service procedures; (4) a 7-percent investment tax credit for the capital cost of the shortwall supports was claimed (as the cost comparison is made on an annual basis, this one-time tax credit was converted to an equivalent uniform annual tax savings); (5) a 48-percent tax rate was used to determine the rate of return after taxes; (6) a 15-percent rate of return was selected as the minimum acceptable to any prospective mine operator evaluating an initial capital investment in a shortwall system; and (7) the mine work schedule was set at two production shifts per day and 220 workdays per year.

Based on these assumptions, the shortwall system generates an additional positive annual cash flow of $366,087 (appendix C). This represents a capital recovery period of 4.3 years to recover the required $1 million estimated current price of a set of shortwall roof supports at 15-percent rate of return. The capital recovery period for the actual initial investment of $430,000 for the shortwall roof supports in 1973 is 1.7 years.

DISCUSSION

Shortwall mining is relatively new in the United States. The first shortwall face was installed in the Federal No. 1 mine in February 1973, and by the end of 1975, five shortwall faces had been installed.[8] Since then at least three additional shortwall faces have begun operating, and several more are in the planning stages. It is felt that as more experience is gained, better methods will evolve, face equipment will improve, and coal production will increase--all of which will improve the economics of shortwall mining.

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[8] Palowitch, E. R., and F. R. Zachar. Shortwall Mining Experience in the United States. Pres. 105th Ann. Meeting, AIME, Las Vegas, Nev., Feb. 22-26, 1976, Preprint 76-F-111, 32 pp.

Significant operational improvements in the system also are possible. A recent study of the availability of the shortwall system showed that it was operational only 68.2 percent of the available working time.[9] Haulage and other non-face-related delays represent an additional 15.7 percent of the available working time. Simulation studies of the system indicated, and experienced proved, that the continuous miner was idle approximately half of the available face time waiting for shuttle-car haulage.[10] If any of the continuous haulage techniques currently under study by the coal industry, the mining machine manufacturers, or the Bureau prove successful, substantial increases in production might be achieved.

The development and extraction of shortwall panels by a single production unit was the more convenient approach for the purposes of this demonstration. This strategy eliminated the loss of coal production at the completion of a shortwall panel (table 7). Because no coal production was being lost, there was ample time to repair and maintain the roof supports between panel moves. Thus, the cost incurred through idle capital equipment was at least partially offset by the high availability of the well-maintained roof support system.

CONCLUSIONS

Experience gained during this demonstration supports the following conclusions:

1. The shortwall unit produced 70 tons of raw coal per day more than an adjacent room-and-pillar unit operating under essentially identical conditions.

2. The estimated direct cost of mining a ton of raw coal by the shortwall method is 18 cents higher than the cost of mining by the room-and-pillar method. The increased cost of depreciating the shortwall roof support system was only partially offset by reductions in the cost of supplies and materials.

3. The profitability of a system that produces an additional 70 tons of coal per day but at an 18-cent-per-ton higher direct cost is a function of the direct operating costs, the fixed and variable indirect costs, the quality of the raw coal, and the selling price of the clean coal.

4. Shortwall mining has been proven a viable alternative to room-and-pillar mining.

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[9] Curry, K. C., D. A. Heimburger, and M. A. Metcalfe. Shortwall Mine Availability Delay Analysis, Phase II, Part I, Technical Analysis. Jet Propulsion Laboratory (Pasadena, Calif.), Rept. 5030-47, Dec. 15, 1976, 52 pp.

[10] Work cited in footnote 7.

APPENDIX A.--ESTIMATED RAW COAL PRODUCED PER 150 FEET OF DEVELOPMENT OR RETREAT

Shortwall Development (Figs. 4-5)

Coal produced = 3 entries × 20 ft wide × 4.5 ft high × 150 ft long
+ 4 crosscuts × 20 ft wide × 4.5 ft high × 30 ft long
= 40,500 + 10,800 cu ft
= 51,300 cu ft × 92.35 lb/cu ft ÷ 2,000 lb/ton
= 2,370 tons

Shortwall Retreat

Coal produced = 150 ft wide × 4.5 ft high × 150 ft long × 92.35 lb/cu ft
÷ 2,000 lb/ton
= 4,675 tons

Room-and-Pillar Development (Figs. 2-3)

Coal produced = 8 entries × 20 ft wide × 4.5 ft high × 150 ft long
+ 14 crosscuts × 20 ft wide × 4.5 ft high × 30 ft long
= 108,000 + 37,800
= 145,800 cu ft × 92.35 lb/cu ft ÷ 2,000 lb/ton
= 6,730 tons

Room-and-Pillar Retreat (at 85-Pct Recovery)

Coal produced = 14 pillars × 30 ft wide × 4.5 ft high × 55 ft long × 92.35
lb/cu ft ÷ 2,000 lb/ton
= 4,800 tons × 85 pct recovery
= 4,080 tons

APPENDIX B.--ESTIMATED MATERIAL COSTS PER TON

Item	Unit price	Shortwall		Room-and-pillar	
		Dev.	Ret.	Dev.	Ret.
Continuous miner bits	$1.55 each	$0.09	$0.09	$0.09	$0.09
Rock dust	$11.00/ton	.08	.04	.08	.04
Machine replacement parts	(1)	.63	.63	.63	.63
Lubricants	(1)	.25	.25	.25	.25
Miscellaneous	(1)	.15	.15	.15	.15
Chock repair and replacement parts	-	.00	.15	.00	.00
Line brattice cloth	$0.41/ft	.02	.00	.01	.03
Posts with caps and wedges	$1.15/set	.00	.01	.00	.33
Cribs	$16.00 each	.00	.01	.00	.00
Stoppings	$43.00 each	.03	.00	.01	.00
Roof bolt complete	$2.15 each	.54	.01	.55	.16
Roof drill bits	$6.00 each	.02	.00	.02	.01
Total	-	1.81	1.34	1.79	1.69
Total (development and retreat combined)	-	$1.50		$1.75	

[1] See BuMines IC 8689.

APPENDIX C.--ANNUAL COST ANALYSIS

	Shortwall	Room-and-pillar
Gross revenue:		
761 clean tons/day x 220 days/yr x $40/ton.....	$6,696,800	-
706 clean tons/day x 220 days/yr x $40/ton.....	-	$6,212,800
Operating costs (see table 14)..................	5,405,305	5,268,333
Gross profit (revenue less operating costs)......	1,291,495	944,467
Depletion (10 percent of revenue)...............	669,680	621,280
Taxable income (gross profit less depletion).....	621,815	323,187
Taxes at 48 percent of taxable income...........	298,471	155,130
Investment tax credit (7 percent of initial cost for 10 years at 15 percent interest)...........	14,000	0
Net profit (gross profit less taxes plus investment credit)............................	1,007,024	789,337
Depreciation (straight line at 10 percent per year)..	221,770	121,770
Annual cash flow (net profit plus depletion plus depreciation)................................	1,898,474	1,532,387
Annual cash flow difference between systems......	$366,087	

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